NAVAL WAR COLLEGE
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EMERGING SATELLITE IMAGING CAPABILITIES AND ITS IMPACT ON U.S. MILITARY OPERATIONS

by

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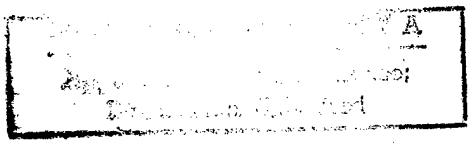
A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.



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15.Abstract: Future U.S. military operations will likely take place with adversaries having access to satellite imagery previously only available to U.S. and Soviet leadership. This change is the result of the rapid improvement in quality and quantity of satellite imagery available from commercial sources. The impact these improvements will have on the capability of commercial imagery to impact future military operations will be profound. Adversaries will be able to observe previously denied geographic areas, see smaller objects, locates these objects more accurately, and observe locations more frequently. U.S. operational commanders and planners will have to account for these capabilities in their operational plans or risk significant losses and potential operational failure. The operational techniques used to effectively deal with these capabilies range from legally restricting satellite access to synchronizing operations with satellite operations. These adaptations will require operational commanders to recognize the risk generated by these systems and the access to them by likely future adversaries of the U.S.

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INTRODUCTION

Up to now, the U.S. operational commander has enjoyed a significant advantage in terms of access to satellite imagery capabilities; in the near future however, these capabilities will be in the hands of U.S. adversaries. With the end of the Cold War and the rapid advancement in technology, satellite imaging capabilities are evolving and expanding at a rapid pace. Increasing use by non super powers and commercialization by U.S. and international companies have expanded exponentially the numbers of those having access to this type of information. What had largely been a super power strategic resource is turning into a commercial commodity openly sold via electronic transmission. Capabilities which were previously of marginal military value have evolved into resources which could have substantial impacts on future military operations. Any ability to control these capabilities has been eclipsed by the rapid spread of the technology worldwide.

Any U.S. operational commander who assumes that the spread of these capabilities will play no role in future military operations risks significant operational losses and the potential for operational failure. Future operational commanders and planners will have to take account of the spread and potential impact of emerging satellite capabilities in their operational plans and designs. To understand the impact, this paper will describe existing satellite capabilities, expected improvements, and examples of operational use. These capabilities will have the most profound impact on an adversary's understanding of operational space and will create new threats to operational protection. As described in this paper, future operational commanders will have to include satellite imagery in an adversary's capabilities and come up with new forms of operational protection to negate its effectiveness.

SATELLITE IMAGERY - WHAT IS IT?

The emergence of satellite imagery as a threat to military operations is a result of the emergence and development of a commercial satellite imagery industry. If this development is now a threat to U.S. military operations, we have no one to blame but ourselves. The impetus for developing this new area of commercial enterprise was the U.S. launching in 1972 of the first Landsat Satellite. This satellite both initiated the commercial satellite imagery industry and also laid the foundation for increased exploitation of computers to make the information gathered more meaningful. The digital form of Landsat imagery linked with the image manipulation software and geographic information systems (GIS) software provided new insight into geographic features on the earth.

Success breeds envy, imitation, and new competitors. The level of interest and activity in Landsat data resulted in France entering the civil satellite imagery market. In 1982 the French successfully launched the Spot imaging satellite, similar to Landsat but also incorporated a number of improvements and new capabilities. Ability to see smaller objects as small as approximately 10 meters and to capture overlapping images providing stereo viewing were significant improvements over the existing Landsat capability. The success of these two satellites systems created sales through 1994 of over $700 million in data and led other nations to view satellite imagery as a viable commercial activity.[1]

An expanding worldwide satellite imagery industry is a result of viewing this imagery as a commercial commodity. Currently satellite imagery is collected and commercial distributed by operators in France, India, Japan, Russia, Canada and the United States. Imagery collected by these systems can be purchased directly from operators or from licensed ground stations. Ground stations to receive Landsat and Spot imagery are found through out the world (21 different nations).[2] In 1995 the Canadian government successfully launched and began collection with a

radar imaging satellite. This satellite imagery provides all weather, night/day capability, vegetation penetration, and can create elevation data sets of the earth's surface. Today it is very much a competitive industry and a buyers market. This competitive market along with the end of the Cold War has created the impetus for a new phase of satellite imagery development.

SATELLITE IMAGERY - RECENT CHANGES AND WHAT'S IN THE FUTURE?

Changes in the capabilities of satellites to be launched in the next several years will be as revolutionary as the change from piston to jet powered aircraft. Releasing to commercial industry of military satellite imagery technology, computer and electronic advances, and national economic competitiveness have all contributed to an emerging satellite imagery industry which will provide greater capability with more capacity at lower costs. Countries and companies are now developing capabilities formerly the exclusive domain of intelligence and military satellites into civil and commercial enterprises. These capabilities will find increasing utilization in natural resource exploitation, land use planning, agriculture, and commercial land development. This increased utilization is expected to grow to a $2.65 billion commercial market by the year 2000.[3] These potential markets have generated significant improvements in the capabilities of satellites to include increased ability to see smaller objects, easier distribution, more capacity, and greater location accuracy.

Image Resolution

The most significant improvement in commercial imagery is in the ability to see smaller objects. This capability is referred to as image resolution and has been the major distinction between existing military and civil satellites. Until the recent launching of an Indian satellite with 6 meter resolution the best civil resolution capability was 10 meter Spot imagery.[4] This imagery has been of marginal military utility and was used to supplement or substitute for military mapping

where no adequate maps existed. Over the next three years the major improvement in this capability will be the launch of 1 meter resolution U.S. commercial satellites and a new 3 meter resolution Canadian radar imaging satellite.[5] Again if these capabilities are a threat to U.S. military operations, the threat comes from ourselves; the U.S. will set the standard and other foreign competitors will be under pressure to match.

What can 1 meter imagery provide? In contrast to the 6 and 10 meter imagery available today, 1 meter imagery will be able to identify significant military features such as communication and radar sites, supply dumps, artillery, types of aircraft and vehicles, missile sites, lines of communication to include their dimensions and composition.[6] These capabilities were once the domain of national intelligence satellites, but now will be readily available to whomever is willing to purchase the imagery and has the capability to exploit. The potential of Canadian 3 meter radar imagery is similar and will also add pressure to competitors to produce 1 meter radar imagery.[7]

Distribution and Capacity

Until recently, distribution of these images was done from a limited number of ground stations via magnetic media or CD ROMs sent to the purchaser. This delivery method has afforded some ability to control distribution but this control will be overcome by new distribution methods. The development of date compression techniques, faster data transmissions, and larger capacity communication lines are all developments of the Internet. These same developments have been incorporated into imagery distribution capabilities and will allow transmission of imagery electronically and via the Internet.[8] Improvements to ground stations are also in development. Based on military development and purchases, satellite operators are developing portable ground receiving stations.[9] The goal of such a portable system would be to place a ground station in one van, reducing its cost, making transport easier and making detection more difficult. The final distribution initiative is a joint venture between a commercial imagery vendor

and Microsoft to build an Internet-accessible archive containing a digital imagery atlas of the earth with 2 meter resolution.[10] This capability will provide access to high quality imagery without the need for requesting new imagery collection from a satellite.

New satellites will significantly increase the total capacity to image the earth. All of the major new commercial ventures plan on placing at least two imaging satellites in orbit. Placing of multiple satellites in orbit will increase the capacity and frequency in which imaging of the earth can occur. Commercial satellite operators will be able improve imaging frequency of a location on the earth from once every 20-24 days to once every 2-5 days.[11] Capacity will also be increased by capabilities to collect and store data onboard the spacecraft. In the past, data has been collected and transmitted directly to earth, limiting the flexibility and capacity to collect areas of the earth.

Accuracy

The last area of significant improvement is the capability to locate objects accurately on the earth's surface. This accuracy will provide future capability to provide a precise three dimensional location of a potential target. This accuracy improvement is a function of computing and electronic advancements, exploitation of GPS satellites, and the designing of imaging systems to collect overlapping images. Lower cost and smaller computer and electronic advancements have allowed commercial operators to place more sophisticated but smaller satellites in orbit at lower cost. Integration of GPS positioning information into the navigation systems of satellites and the derivation of ground control points allow significant improvements in developing of accurate ground coordinates. Overlapping images will provide the opportunity to view these images in stereo and exploit traditional aerial photography techniques to derive coordinates with significant accuracy improvements. These improvements will result in the determining of ground locations from imagery within 10 meters of their actual location.[12]

SATELLITE IMAGERY - WHY DOES IT MATTER?

Will these improvements really have an impact on military operations? Commercial satellites have existed for two decades and has played a limited role in recent conflicts; can they be decisive in the future? While yesterday's satellite imagery may have been of limited operational value, future imagery capability can be decisive in military operations. The increased resolution, capacity, frequency, and accuracy will provide capability to an adversary which, properly exploited, could be decisive. An adversary will have access to information which will provide a far better understanding of the operational factor of space. Operational protection will also need to adapt and account for an adversary's use of this improved capability.

Operational Space

The importance and impact of operational space in relation to military operations has been recognized by military theorists. Clausewitz concluded:

> This relationship, to begin with, is a permanent factor - so much so that one cannot conceive of a regular army operating except in a definite space. Second, its importance is decisive in the highest degree, for it affects the operations of all forces, and at times alters them. Third its influence may be felt in the smallest feature of the ground, but it can also dominate enormous areas.[13]

But even before Clausewitz, Sun Tzu identified the importance of operational space:

> Conformation of the ground is of the greatest assistance in battle, Therefore, to estimate the enemy situation and to calculate distances and the degree of difficulty of the terrain so as to control victory are virtues of the superior general. He who fights with full knowledge of these factors is certain to win; he who does not will surely be defeated.[14]

The ability to understand the space where you are or which you will occupy along with the space your opponent occupies can provide decisive insight into to future operational actions. Recent developments in satellite imaging capability will significantly improve any adversary's

understanding of the factor of space. Operational blunders seen in recent conflicts could be eliminated by increased exploitation of commercial imagery for a better understanding of operational space.

The Falklands War showed the need for this information and the limited ability to acquire it. Neither the British or the Argentineans possessed adequate geographic knowledge of Falklands Islands. The British were able to exploit local knowledge to development a sense of the space of the Falklands, select a landing area, and identify the decisive geographic features. Had Argentina had access to the new satellite capabilities, they could have collected and analyzed imagery information which would have provided a three dimensional appreciation of the islands. This knowledge could have lead to a different Argentinean approach to countering British activity. Use of Argentinean aircraft and artillery against the limited British lines of communication, destruction of British helicopters, reinforcement of strategic locations, and assembling of a more mobile Argentina military force could have had significant impacts on the British success. The British were able to prevent Argentinean access to the limited commercial satellite imagery through their relationships with the only two commercial providers, France and the United States. At the same time, Britain was able to exploit military and intelligence relationships with the U.S. to receive access to imagery unavailable to Argentina.

Similar to Argentina, Iraq faced an opponent with superior knowledge of operational space. The U.S. and its allies were able to use military and commercial imagery to gain more effective knowledge of both the space they were defending and the space in which they would take the offensive. Coalition use of Landsat and Spot imagery was a substitute for maps in some cases or as a means to improve or supplement existing maps. This imagery provided insight into operational space for planning coalition operations.

Iraq had not exploited similar opportunities before the war to better understand their space and the space from which a coalition offensive would emerge. Prior to their invasion of Kuwait, Iraq could have purchased and exploited commercial imagery to derive limited space awareness. They had exploited and demonstrated this capability in their war with Iran.[15] With the invasion of Kuwait, Iraq was subject to U.N. sanctions, effectively cutting them off from any supply of commercial imagery from the U.S. or France. If such imagery had been available to Iraq, they could have identified, accurately located and assessed the utilization of fixed and permanent coalition facilities such as ports, airfields, key road intersections, radar and communication facilities. Instead of believing that the terrain and local roads would not support such a massive attack on their flank, the Iraqi's could have anticipated and prepared for the potential flanking movement.[16]

The importance of knowledge of operational space will lead potential adversaries to exploit the availability of the improved satellite imagery capability. They will likely combine this with the readily available commercial software and geographic information systems (GIS) to prepare future storehouses of information on the operational area of their choosing (areas which may have been denied to them and traditional means of reconnaissance). Improved commercial imagery, utilizing currently commercially available software and GIS systems, can provide knowledge of the terrain, soil types, surface ruggedness, vegetation cover, impact of climate on the surface, and distance between critical locations and facilities.[17] Expertise to analyze this information is widely available from a trained workforce utilized to support non military activities such as land use planning, site evaluation and resource exploration. Acquisition of this type of information can take place well before an operation and cover geographic areas U.S. commanders may have thought off limits. U.S. operational commanders will have to recognize that their adversaries will likely have as good or better insight into the nature of the operational space, insight the adversary will exploit in a manner most favorable to his objective.

Operational Protection

Operational protection will be altered and challenged in new ways by the increasing availability and higher quality satellite imagery. These improvements will have impacts on all forms of warfare, from terrorist activities to massive movements of troops and equipment. With the improved capability, adversaries will be able to detect, identify, and target operational activity at a level usually only possible up to now by utilizing the national intelligence assets of the U.S. and Russia. Operational maneuvers such as that utilized by coalition forces during Desert Storm would be detected in the future by widely available high quality commercial imagery. Operational commanders and planners who are charged with protecting their own center of gravity will be confronted by new and expanding challenges.

Improved resolution of the new imagery capabilities will allow adversaries to more readily distinguish military from civilian activity. This commercial capability will improve from the present simple detection of an airport to being able to distinguish civilian versus military airport activity and the types of military aircraft at that airport. Major areas of logistical support will be identifiable through the uniqueness of the types of vehicles, supplies, and weapons systems used by the military, all features more readily identified with higher resolution imagery. The unique signatures of communication equipment associated with command and control facilities will appear in new imagery; large antennas, satellite ground stations, and radar domes will be clearly identifiable.[18] With types of military units discernible, infantry versus armor locations could provide insight into potential weak points or indications where offensive action may begin. Improved resolution capabilities will also improve an adversary's ability to realistically simulate, game, plan, and train against U.S. operational movements, maneuvers and the impacts of potential branches and sequels. Technology found in computer games, commercial flight simulators, and multimedia systems will all improve exploitation of imagery data and provide realism in its use by an adversary.

Improved capacity and frequency of imagery collection will provide both temporal and qualitative information on operational activity. The ability to use multiple satellites to capture imagery as often every other day over a particular location is a significant improvement from the earlier commercial imagery capabilities typically measured in weeks.[19] This frequency of collection will allow insight into the magnitude and patterns of operational activity, how often forces move or practice, and whether they have lulls in activity at particular times. It can also show cycles of activity such as a pattern of supply resulting in a particular time of lowest readiness and sustainment.

Specific types of imagery newly available will also present operational protection challenges. Radar versus infrared versus visible imagery sensors will make camouflage and deception more difficult.[20] Through the use of multiple types of satellite imagery, metal and engine heat of real vehicles are easily distinguished from any camouflage created from plastic or wood . In addition, all of these methods of looking for change over time are becoming automated in available commercial software. Change detection is used in a number of applications such as resource detection and land use planning, making these techniques widely known and easily acquired. Adversaries will be able to monitor indications of change over large geographic areas utilizing the increasing computer capabilities commercially available.

The final improvement in imagery is in increased accuracy in determining the geographic location of an object on the earth. This increased accuracy parallels the increased accuracy of weapons systems and commercial / military guidance systems. Weapon accuracy is dependent on both the accuracy of the weapons guidance system and the accuracy of the target's determined location. This improvement in accuracy will allow adversaries to utilize weapons against an operation more precisely (and effectively). High value targets and soft targets will be at more risk. The success of the Iraqi Scud war would have been much greater if they had been able to more effectively identify and attack targets. When one considers the Scud attack on Dhahran

killing 28 U.S. personnel, it is obvious that Iraq could have greatly increased the number of U.S. casualties with more accurate targeting. More accurate location information will also make more feasible the use of asymmetrical and terrorist attacks against specific identified and located targets such as headquarters and C^2 facilities.[21] This ability to locate more accurately will make fixed locations more vulnerable. Buildings, airports, ports, railroads, and roads will likely be accurately located before an operation begins, stored in a target database which an adversary can exploit as needed.

The value of this imagery is describable, but is there any evidence of its actually use? During the Iraq / Iran War the Iraqis did exploit commercial satellite imagery in their military operations. They also attempted to purchase imagery after the initiation of the Gulf War.[22] Studies of French Spot imagery collection have shown a high degree of correlation between where imagery has been requested and what would be thought of as "military" or "strategically" significant locations.[23] Significant amounts of Spot imagery have been collected over the Israeli nuclear installations, the Pakistani nuclear facilities, the Golan Heights and regions in the Persian Gulf.[24] Recently CBS news reported on a US SPACECOM study which demonstrated that imagery could be very easily requested from commercial vendors. This ease was demonstrated by a recent SPACECOM request for imagery over Bahrain with no inquiry by the vendor on who was requesting, all that was needed was a VISA charge number.[25] SPACECOM also discovered a significant amount of requests by someone, identity unknown, for imagery over U.S. military installations.[26] This trend will continue as the imagery's utility increases and the costs go down.

SATELLITE IMAGERY - WHAT CAN THE OPERATIONAL COMMANDER OR PLANNER DO ABOUT IT?

In facing the potential impact of commercial satellite imagery the operational commander and planners have multiple methods of negating or denying this potential. Use of "shutter control" to

deny an adversary access to imagery, combating his means of exploiting it, deceiving him if he has it, and synchronizing operations with his access are all methods of accounting for this emerging threat to operational protection. These techniques used early in the planning process and effectively during an operation will reduce the utility of commercial imagery to an adversary.

Shutter Control

A means of control is the concept of "shutter control" or simply turning the satellite off, thus restricting distribution of imagery over significant military areas. U.S. satellite operators can legally be directed by the Secretary of Commerce in consultation with the Secretaries of Defense and State to control access to their satellites and imagery.[27] This "shutter control" is only to be exercised when national security will be impacted. Operational commanders should exploit this legal authority through the Secretary of Defense as early as possible, denying access to imagery requests previously established by an adversary or third party which could compromise operational protection.

There are difficulties and limitations to this legal "shutter control." While all parties have agreed that military operations are covered by this control, there has been disagreement about the ability to exert "shutter control" during non military operations which may have national security implications.[28] Further objections to this control have come from the press who have exerted their first amendment rights and will only recognize court action to implement "shutter control" authority.[29] "Shutter control" protects against current and future imagery collection, but has no impact on previous collection and foreign satellite operators. A similar technique to attempt to control foreign satellite operations would be for the U.S. to purchase all the satellite collection opportunities over an area of interest, thereby excluding other parties from this imagery. A final control on uncooperative foreign satellite operators might be excluding them from future sales of their imagery to the U.S. government. The U.S. government has been a significant purchaser of

commercial imagery and any threat to exclude would have a significant financial impact on the foreign satellite operator.

The ultimate in satellite imagery shutter control would be to employ antisatellite weapons to destroy, disable, or blind imaging satellites. Antisatellite weapons could be used to exercise self defense against an adversary's imaging satellite, but the difficulty with this concept is that in all likelihood the operators of imaging satellites will be a third party nation or company. The U.S. has endorsed an open skies policy for three decades and to ignore that policy in times of conflict would open up U.S. satellites to similar attacks.[30] It seems unlikely that senior U.S. decision makers would authorize destruction of any third party satellite without clear and defensible evidence of its threat to U.S. operations.

Information Warfare

If the operational commander or planner believes that his adversary possesses the capability to receive and exploit satellite imagery there still are a number operational actions which can be employed to counter this threat. First and foremost is to treat the ability to exploit as part of any informational warfare plan. This plan should account for any satellite receiving ground stations and communication links. Information warfare such as viruses could also be inserted against the commercial software used to exploit satellite imagery . The difficulty with information warfare against commercial satellite imagery and technology is that it is largely an open competitive market. As ground stations get smaller and more portable, the software to exploit becomes more widespread, and the level of computer support required goes down; this results in a capability easily reproduced and deployed.

Deception

While the previous means of impacting the ability to exploit imagery were largely actions to deny access or impede utilization, the operational commander and planner can take actions within their operation which can diminish the impact of satellite imagery. Two areas of operational planning which can be utilized to negate this capability are operational deception and synchronization. If an operation is able to limit but not totally deny an adversary's access to satellite imagery, then utilization of camouflage, hiding of activity in vegetation, or under overhead structures, can degrade imagery information on operational intentions. Conversely, an operational commander can deliberately display operational activity or resources to imply a deployment or attack in a direction.[31] This display may result in an adversary's reaction creating favorable conditions for the operational commander elsewhere or result in an adversary unwilling to confront perceived superior forces.

Synchronization

The operational commander can also synchronize activity to avoid times when overhead satellites are in the area. Satellite paths and times of observation are regular, predictable, and publicly available, allowing operational synchronization to avoid detection.[32] Understanding climatic and weather conditions could allow an operational planner to use cloud cover to deny satellites visual imagery collection (as opposed to radar). Cloud cover would only have to be partial and high enough to obscure the area of interest and would not require low heavy cloud cover possible impacting air operations. Climatic patterns such as rainy versus dry seasons will provide long range operational synchronization information. Delaying operational movement and maneuvers until an increased likelihood of cloud cover would reduce useful imagery collection opportunities. All of these synchronization actions would be more effective where the adversary has few imagery collection assets available. Use of legal "shutter control" and building a coalition

inclusive of commercial imagery producers would limit adversary access to imagery and provide opportunities for operational synchronization.

Assumption of Previous Access

The operational commander and planner must account for the possibility that an adversary has previously had access to satellite imagery. This assumption should result in operational plans which minimize concentration of operational resources for long periods of time at fixed and easily identified locations. Use of temporary facilities, movement of forces, and dispersing high value assets are all approaches which recognize that not only may an adversary have the capability to strike them, but also the capability to identify and locate them as a target.

CONCLUSION

Today's operational commanders and planners will be facing capabilities in the hands of adversaries not foreseen 10 years ago. With the end of the cold war and technological advancements, satellite imagery has been transformed from a strategic intelligence asset to a commercial technology competing in a world market. These changes will make the availability and exploitation of satellite imagery a reality for both sides in any future military operation. For U.S. operational commanders and planners to produce a successful military operation, adaptation to the reality of imagery in the hands of an adversary will be necessary. In this environment, operations which are designed around precluding imagery collection where possible and incorporating operational security and deception when needed will have the best chance of succeeding. Ignoring the possibility of imagery collection will place the adversary in the position of clearly seeing our intentions, discovering our weakness, and reacting faster and decisively to our actions. The genie is out of the bottle and we will not be able to put her back in.

NOTES

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[2] Thomas G. Mahnken, "Why Third World Space Systems Matter," Orbis, Fall 1991, 567.

[3] Bill Sweetman, "Spy Satellites: The next leap forward," International Defense Review, January 1997, 30.

[4] Joseph C. Anselomo, "Spot Sees Little Threat From 1-Meter Systems," Aviation Week & Space Technology, 16 March 1998, 43.

[5] Warren Ferster, " U.S. Firms Demand Parity to Radarsat 2," Space News, 9 March 1998, 1.

[6] Ann M. Florini, "The Opening Skies: Third-Party Imaging Satellites and U.S. Security," International Security, Fall1988. 98.

[7] Ferster, " U.S. Firms Demand Parity to Radarsat 2." 28.

[8] Vipin Gupta, " New Satellite Images for Sale," International Security, Summer 1995, 105.

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[11] Gupta, 102.

[12] Ibid.

[13] Carl von Clausewitz, On War, (Princeton: Princeton University Press, 1976) 109.

[14] Sun Tzu. The Art of War, (London: Oxford University Press. 1963) 127.

[15] Mahnken, 568.

[16] Steven Lambakis, "Space Control in Desert Storm and Beyond." Orbis, Summer 1995, 417.

[17] Lane 22.

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[19] Gupta, 102.

[20] Sweetman, 32.

[21] Lane, 23.

[22] Manhnken, 568.

[23] Peter D. Zimmerman, " From the SPOT files - Evidence of Spying," Bulletin of Atomic Scientists, September 1989, 24-25.

[24] Ibid.

[25] David Martin, " Spy Images for Sale," CBS Evening News, 28 April 1998.

[26] Ibid.

[27] Warren Ferster, " Industry Outcry May Scuttle Plan To Regulate Commercial Industry." Space News, 6 April 1998, 3.

[28] Ibid.

[29] Congress, House, Committee on Science, The Commercial Space Act of 1997, Parts I-III. Hearing before the Subcommittee on Space and Aeronautics, 105 Cong., 1st sess., 21 May 1997, 86.

[30] Ibid.

[31] Gupta, 114.

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